

1

(a) Wien's displacement law for black body radiation is given by

$$\lambda_{\max} T = \text{constant.}$$

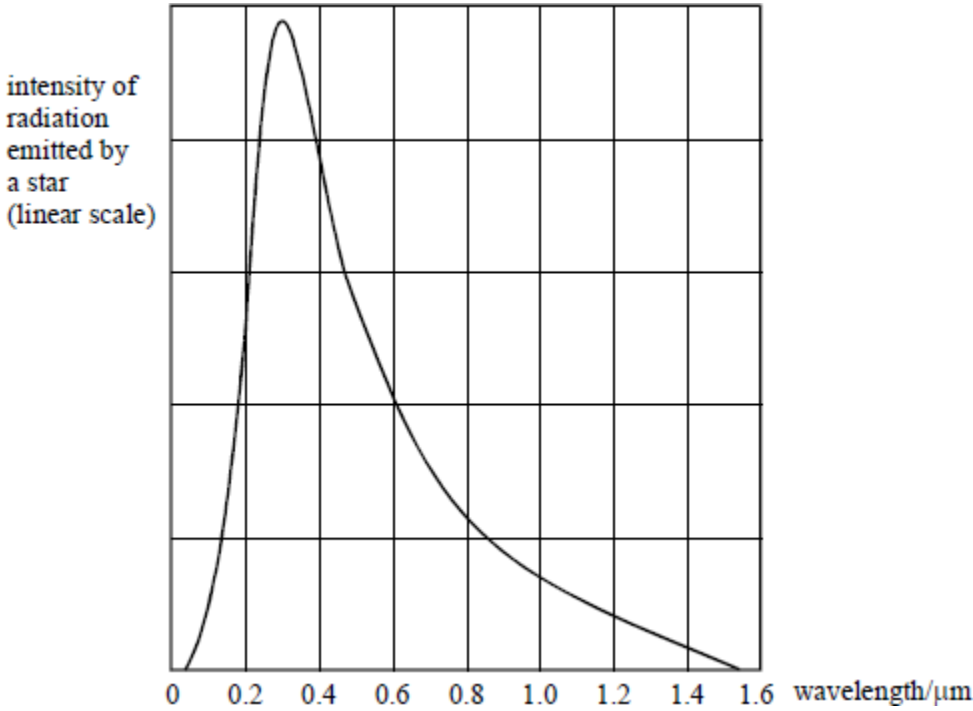
State the meaning in this equation of  $\lambda_{\max}$ .

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(1)

(b) The black body radiation curve for a certain star is shown in **Figure 1**.



**Figure 1**

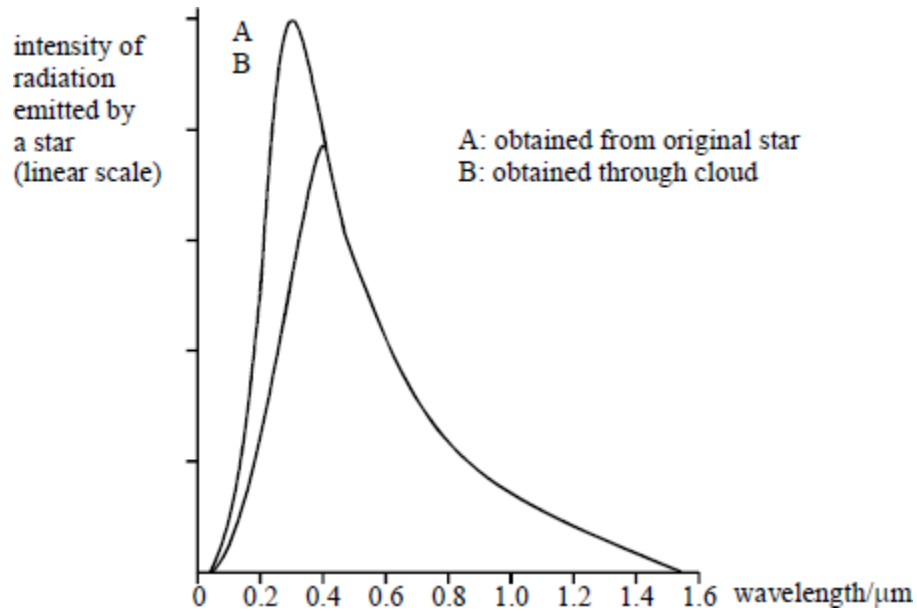
Calculate the temperature of the star, given that the Wien constant is  $2.9 \times 10^{-3} \text{ m K}$ .

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(2)

- (c) **Figure 2** shows the effect on the radiation from the star of a cloud layer that does not absorb the light evenly at all wavelengths.



**Figure 2**

- (i) State the range of wavelengths absorbed most strongly by the cloud.
- \_\_\_\_\_
- (ii) Explain why this absorbing cloud alters the estimate of the temperature of the star. Would the new estimated temperature be greater or less than the original temperature?

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**(3)**  
**(Total 6 marks)**

**2**

(a) The table summarises the properties of five of the stars in the constellation of Cassiopeia.

<b>name</b>	<b>absolute magnitude</b>	<b>apparent magnitude</b>	<b>spectral class</b>
Achird	4.6	3.5	G
Chaph	1.9	2.3	F
Ruchbah	0.24	2.7	A
Segin	-2.4	3.4	B
Shedir	-0.9	2.2	K

Explaining your answer in each case, state which star

(i) is the hottest,

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(ii) is likely to appear orange in colour,

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(iii) appears the brightest from Earth,

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(iv) is less than 10 pc away from the Earth.

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(4)

(b) The constellation Cassiopeia contains another star with an apparent magnitude of 2.2, absolute magnitude of  $-4.6$  and a surface temperature of  $12\,000\text{ K}$ . Calculate, for this star,

(i) its distance from the Earth,

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(ii) the peak wavelength in its black body radiation curve.

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(3)

(Total 7 marks)

**3** The table gives information on two stars.

star	apparent magnitude	spectral class	distance/pc
Proxima Centauri	11	M	1.30
Antares	1.0	M	160

(a) (i) Explain what is meant by

*apparent magnitude* \_\_\_\_\_

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*absolute magnitude* \_\_\_\_\_

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(ii) The two stars named in the table are viewed through a telescope. State and explain **one** difference in the appearance of the two stars.

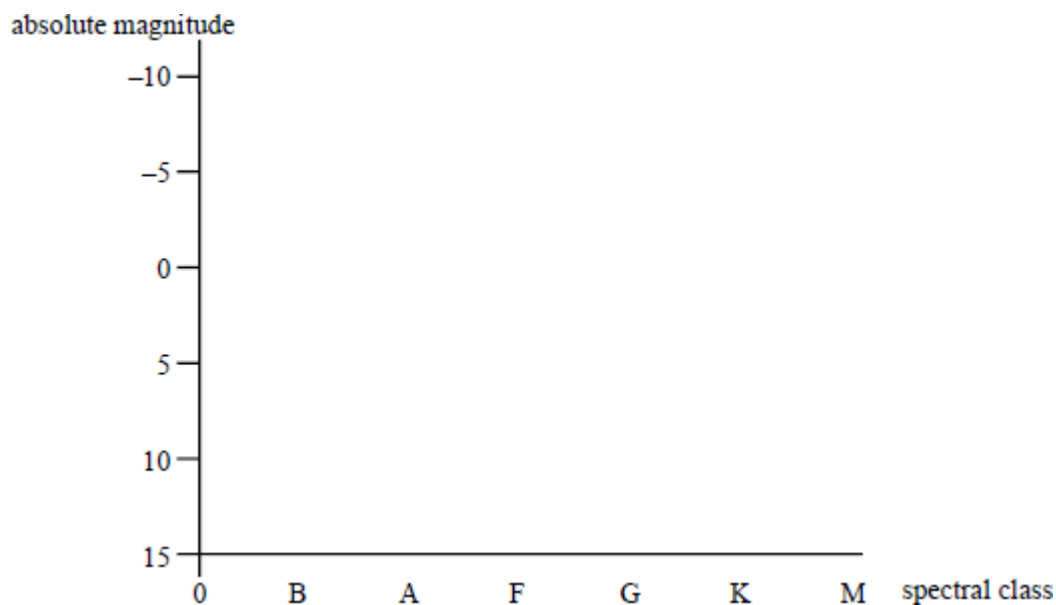
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(4)

- (b) (i) Draw a Hertzsprung-Russell diagram for main sequence stars, Giant Stars and White Dwarfs.



- (ii) With reference to the table, calculate the absolute magnitude of Proxima Centauri.

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- (iii) Given that the absolute magnitude of Antares is  $-5$ , mark and label with an X its approximate position on the Hertzsprung-Russell diagram.

(6)

- (c) (i) Giving your reason, what can you say about the surface temperature of the two stars?

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- (ii) Hence, deduce which star has the larger diameter. Explain how you arrive at your answer.

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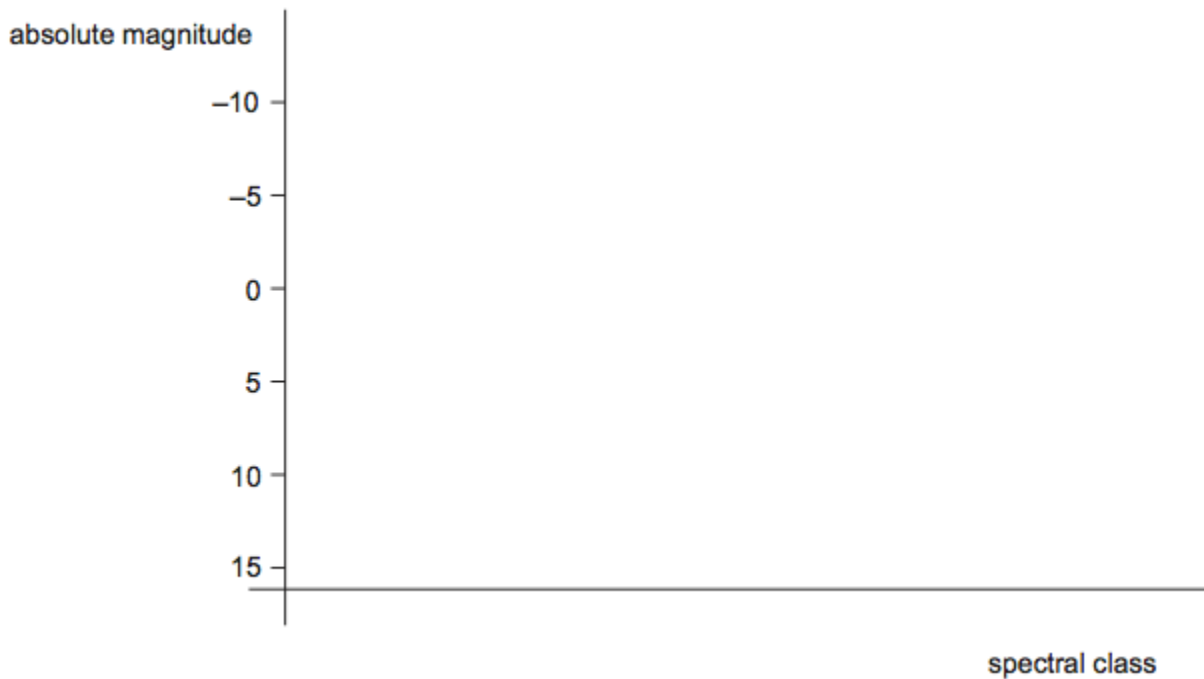
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(4)

(Total 14 marks)

**4**

(a) The graph shows the axes of a Hertzsprung–Russell (H–R) diagram.



(i) Label the spectral class axis with a suitable scale.

(1)

(ii) Complete the H–R diagram by marking the positions of the main sequence, dwarf star and giant star regions.

(2)

(b) The table summarises some of the properties of three stars in the constellation Aries.

Star	Apparent magnitude	Temperature / K	Radius / m
Hamal	2.0	4500	$1.0 \times 10^{10}$
Sharatan	2.7	9000	$1.8 \times 10^9$
41 Arietis	3.6	12000	$9.6 \times 10^{10}$

(i) With reference to the data in the table, compare the three stars.

Your answer should include a discussion of:

- the appearance to the naked eye of the three stars as seen from Earth
- the spectrum of the three stars
- the region of the Hertzsprung–Russell diagram to which each star belongs.

The quality of your written communication will be assessed in your answer.

(6)

- (ii) Hamal is 66 light years from the Earth.  
Calculate the absolute magnitude of Hamal.

absolute magnitude = \_\_\_\_\_

**(3)**

- (iii) Identify which star is the greatest distance from Earth.  
Explain your answer.

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**(3)**

**(Total 15 marks)**

5

Figure 1 shows the black body radiation curves for three stars, labelled P, Q and R.

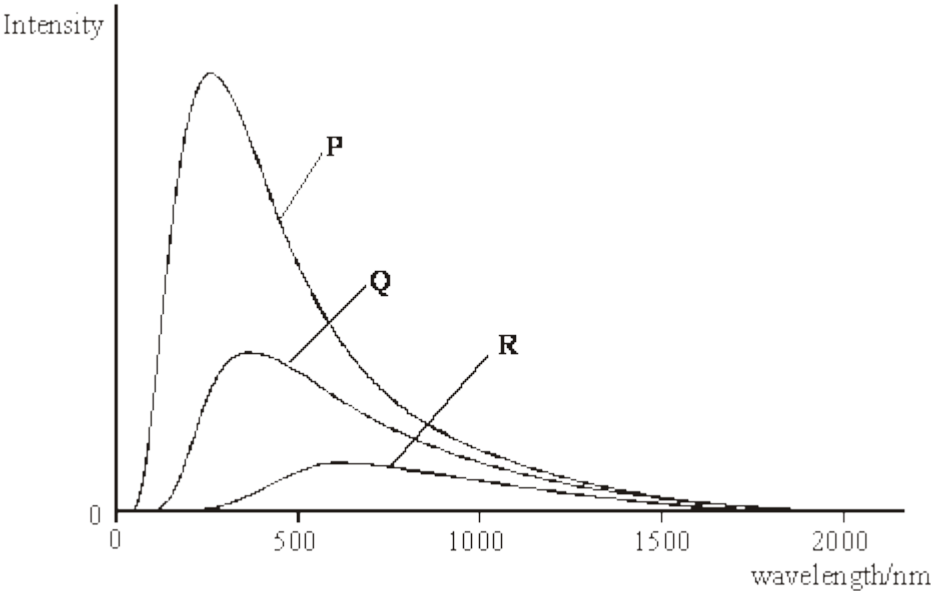


Figure 1

(a) (i) State and explain, without calculation, which one of the three stars is the hottest.

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(ii) Calculate the black body temperature of the hottest star.

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(3)

(b) More detailed analysis of the hottest star's spectrum revealed the presence of Hydrogen Balmer absorption lines.

(i) For which two spectral classes are these lines the prominent feature?

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(ii) Describe how these absorption lines are produced in the spectrum of a star.

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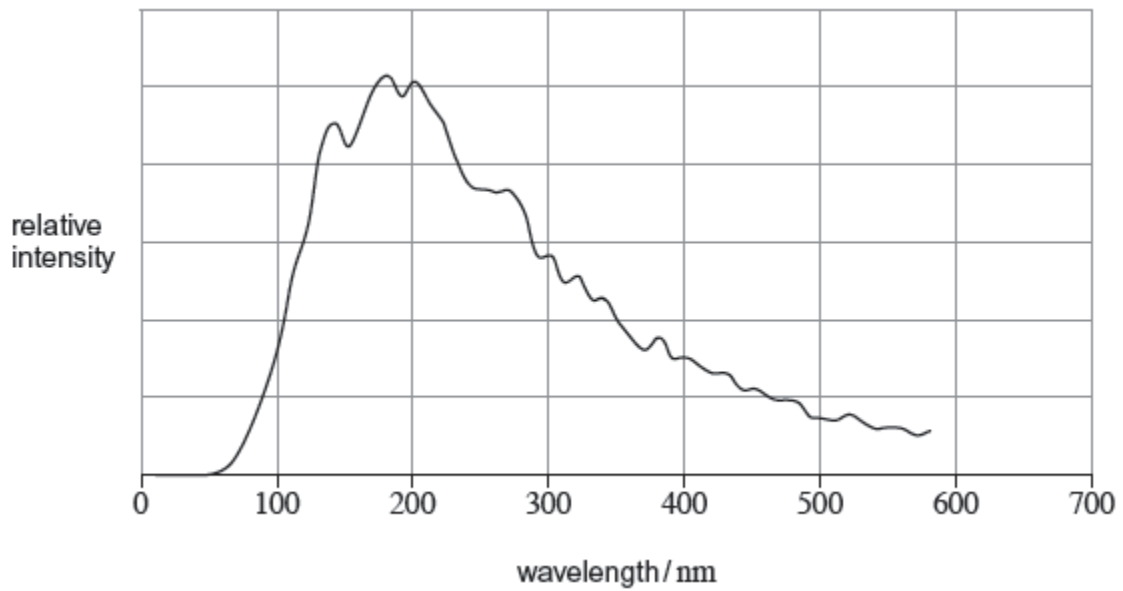
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(4)

(Total 7 marks)

6

The graph shows the variation of intensity with wavelength for the star 40 Eridani B.



- (a) (i) Calculate the black body temperature of 40 Eridani B.

State an appropriate unit for your answer.

temperature = \_\_\_\_\_ unit \_\_\_\_\_

(3)

- (ii) 40 Eridani B has a total power output of  $4.2 \times 10^{24}$  W.

Calculate its radius.

radius = \_\_\_\_\_ m

(2)

- (b) (i) Which of the following regions of the Hertzsprung-Russell diagram does 40 Eridani B belong to?

Tick (✓) the correct answer.

<b>main sequence</b>	
<b>dwarf star</b>	
<b>giant star</b>	

(1)

(ii) Give reasons for your answer to part (i).

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(2)  
(Total 8 marks)

7

The table compares two properties of the Sun with Arcturus, a star in the constellation Bootes.

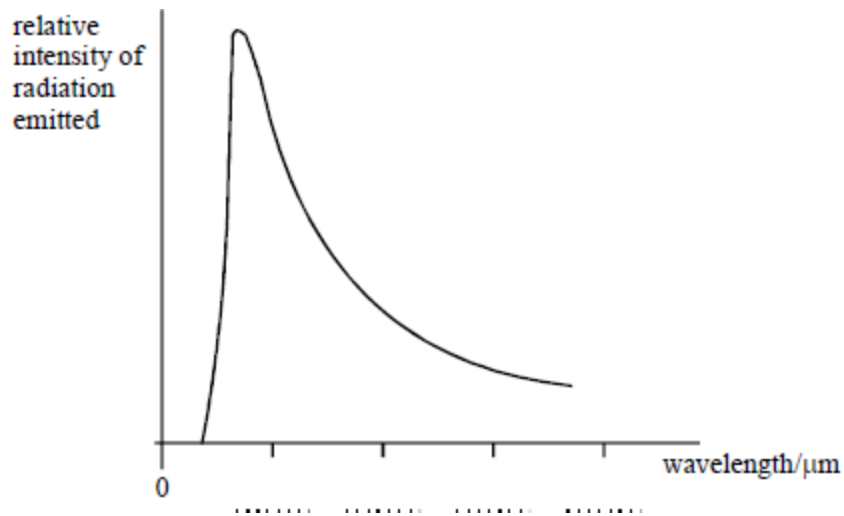
	Sun	Arcturus
surface temperature/K	6 000	5 000
absolute magnitude	5	0

(a) (i) Assuming the Sun acts as a black body, calculate the wavelength at which maximum emission occurs in its spectrum.

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(ii) The graph shows the black body radiation curve for the Sun. Use your answer to (i) to enter values on the wavelength axis in the 4 places provided.



(iii) Without calculation, sketch on the axes above a black body curve for Arcturus.

(4)

- (b) (i) Explain how the information in the table indicates that Arcturus is 100 times brighter than the Sun.

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- (ii) Assuming that the power output of Arcturus is 100 times greater than that of the Sun, show that its surface area must be approximately 200 times greater.

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(4)

(Total 8 marks)

8

The Summer Triangle consists of three stars, Altair, Deneb and Vega. Some of the properties of the three stars are summarised in the table below.

	<b>Altair</b>	<b>Deneb</b>	<b>Vega</b>
surface temperature / K	7700	8500	9600
apparent magnitude	0.77	1.25	0.03
absolute magnitude	2.21	-8.38	0.60

- (a) The three stars belong to the same spectral class.

State and explain which spectral class they belong to.

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(2)

- (b) Deduce which of the three stars appears brightest.

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(2)

(c) Calculate the distance from Earth to the closest of the three stars.

distance = \_\_\_\_\_ pc

**(3)**

(d) Deduce which of the three stars is the largest.

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**(3)**

(e) Calculate the wavelength of the peak in the black body radiation curve of Altair.

wavelength = \_\_\_\_\_ m

**(2)**

**(Total 12 marks)**

9

(a) The table summarises some of the properties of two stars in the constellation of Ursa Minor.

name	apparent magnitude	<u>radius of star</u> radius of the Sun	spectral class
Polaris	2.0	50	F
Kocab	2.0	50	K

(i) Using these data, describe and explain **one** similarity and **one** difference in the appearance of the two stars as seen with the unaided eye by an observer on the Earth.

similarity\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

difference\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

(2)

(ii) Deduce which of the two stars is further from the Earth.

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

(3)

(b) Ursa Minor also contains the galaxy NGC 6251. Measurements indicate that the light from the galaxy has a red shift,  $z$ , of 0.025 and that the galaxy is 340 million light years from Earth.

(i) Use these data to calculate a value for the Hubble constant.

value \_\_\_\_\_  $\text{k ms}^{-1} \text{ Mpc}^{-1}$

(3)

(ii) Use your answer to part (b)(i) to estimate a value for the age of the Universe. State an appropriate unit for your answer.

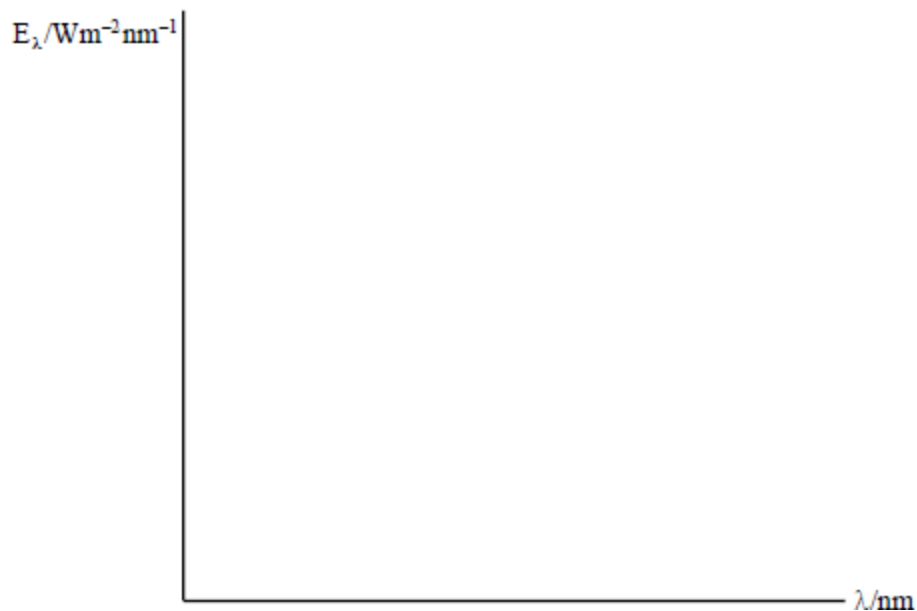
age \_\_\_\_\_ unit \_\_\_\_\_

(3)

(Total 11 marks)

10

(a) Using the axes below, sketch the emissive power of a black body,  $E_\lambda$ , as a function of wavelength for each of three temperatures, 1000K, 1200K and 1600K. Indicate the temperature on each curve.



- (b) (i) *Wien's displacement law* may be written as  $\lambda_{\max}T = \text{constant}$ . State what  $\lambda_{\max}$  represents.

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- (ii) Obtain the value of the constant from the Data booklet and calculate  $\lambda_{\max}$  for a temperature of 1600K.

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- (iii) Assuming that  $\lambda_{\max}$  for the Sun lies within the range of the visible spectrum, use Wien's law to estimate the temperature of the Sun.

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(5)

- (c) Stefan's law for a black body may be written as  $E = \sigma T^4$  where  $E$ , the energy radiated per second per square metre of the surface area, has units  $\text{W m}^{-2}$ .

- (i) Hence state how a value of  $E$  may be obtained from one of the curves drawn in part (a) for a given temperature.

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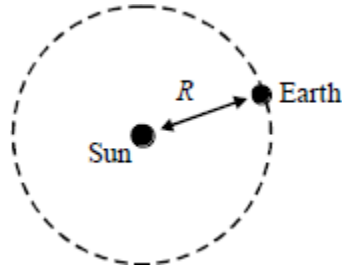
- (ii) For a black body of surface area  $A$ , give Stefan's law in the form which gives total radiative power of the body.

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(2)

- (d) (i) The diagram represents the Earth in orbit around the Sun. Given that the Earth receives  $1400 \text{ W m}^{-2}$  of energy from the Sun and that the Sun emits energy equally in all directions, estimate the total output power, in  $\text{W}$ , of the Sun.

mean radius,  $R$ , of the Earth's orbit around the Sun =  $1.5 \times 10^{11} \text{ m}$



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- (ii) Hence, use Stefan's law to deduce the temperature of the Sun.

radius of the Sun =  $7.0 \times 10^8 \text{ m}$

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(4)  
(Total 14 marks)